6 GHz Low Power Indoor (LPI) Wi-Fi / Fixed Service Coexistence Study

6 GHz Wi-Fi Is Essential to 10G

CableLabs®

- The cable industry has nearly saturated its US footprint with gigabit broadband service
- Gigabit broadband is the foundation of 10G, which CableLabs is building along with our members
- Wi-Fi is how consumers access their broadband service, and the Wi-Fi link must perform at the same level
- Wider channels, greater bandwidth, higher efficiency provided by 6 GHz Wi-Fi is essential to the realization of 10G
- Multi-gigabit, low latency, highly reliable broadband is the 10G vision, but additional unlicensed spectrum is required to make this a reality

Executive Summary

- There have been many technical analyses filed in the FCC record in the 6 GHz proceeding
- CableLabs recognizes the importance of suitable incumbent protection in the 6 GHz band
- CableLabs has worked with its members to gather real-world airtime utilization data as a key input to 6 GHz coexistence analysis
- Analysis incorporating operational network data proves that LPI Wi-Fi can coexist with FS without harmful interference
  - Conservative simulation of aggregate noise incorporates this Wi-Fi airtime utilization data and other real-world data such as LIDAR ranging and realistic ranges for relevant parameters, which shows that I/N does not reach even the conservative -6 dB threshold
  - We increase the robustness of our conclusion through a sensitivity analysis that shows that even unrealistically high levels of noise that exceed our simulation-based observations do not impact FS availability

Wi-Fi Airtime Utilization Data

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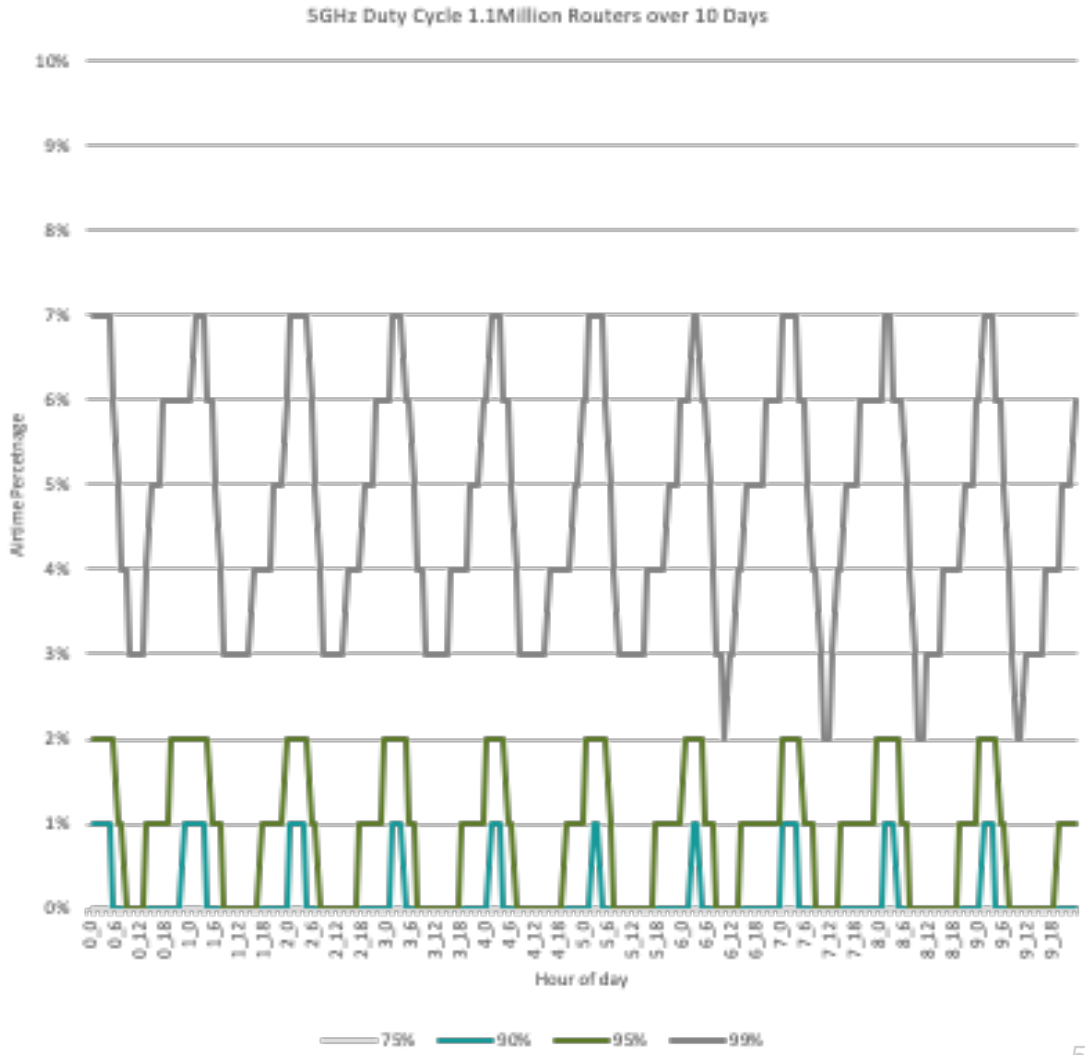
- 500,000 Wi-Fi access points were polled for airtime utilization
- 15-minute measurement intervals, hourly, 24 hours/day over 10 days
  - All Wi-Fi activity, data and management frames
- Wide geographic representation in AP sample
- Yielded 450 million data points, representing the most comprehensive data set available on the record
- This data was recently filed by Broadcom in a Dec. 9th Ex Parte

Wi-Fi Airtime Utilization Data

- 5 GHz Measurement results:
  - 99th percentile peak utilization is 7%
  - 95th percentile peak is 2%
  - 90th percentile peak is 1%

➢For entire data set, weighted average is 0.4%



Wi-Fi Airtime Utilization Data: Analysis

- We can use the full data set to analyze coexistence between LPI Wi-Fi and FS. We accomplish this through two approaches:

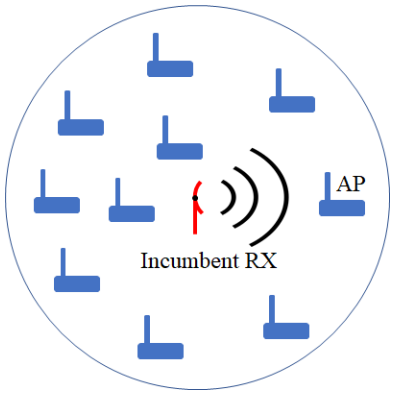
    1) A realistic simulation of aggregate interference to a representative FS link (New York City case study)
    2) A sensitivity analysis of what unrealistically high levels of noise from Wi-Fi mean for FS availability

- We can also use this data to anchor existing technical studies on the record

Interference Simulation

Aggregated RLAN interference to a representative FS link in Manhattan, using real-world Wi-Fi activity data

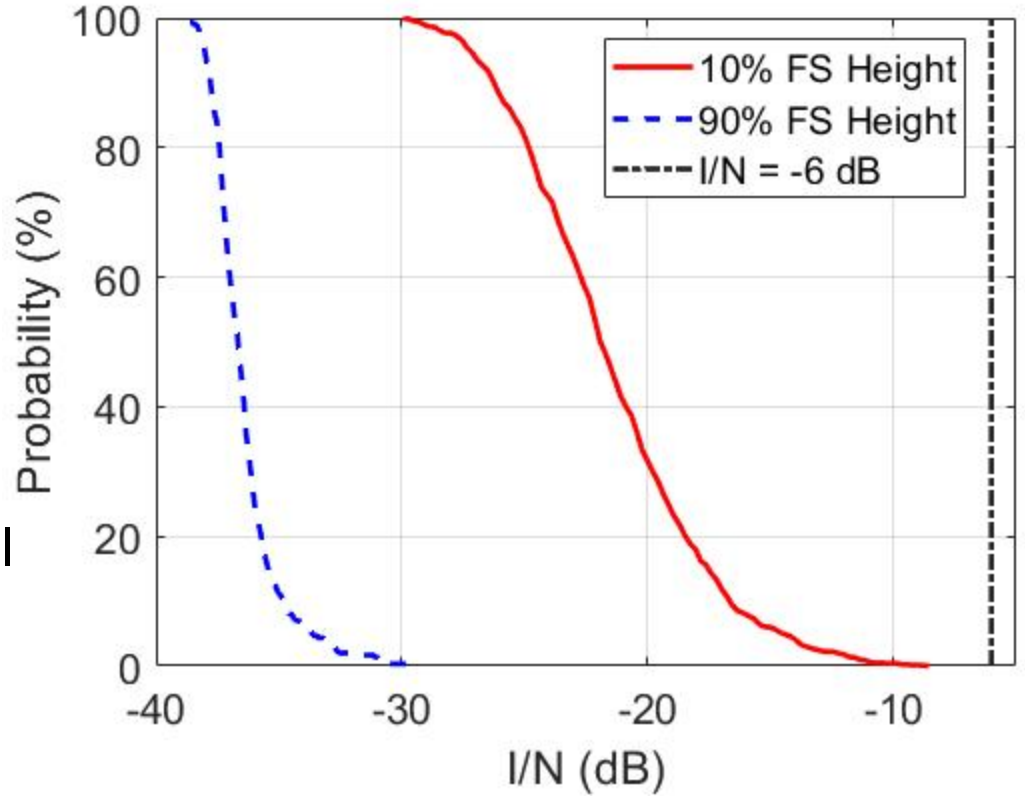
Method



- Derive aggregate RLAN interference to a representative FS link in NYC, using real-world RLAN airtime utilization data and reasonable ranges of relevant parameters, including:
  - Aggressive 6 GHz RLAN growth (1,000 APs/km^2 using 6 GHz) and accurate in-market deployment (including height from USGS LIDAR data)
  - Realistic and appropriate distributions of RLAN channel bandwidth, power and antenna pattern, path and building loss
  - Representative FS link in Manhattan using actual antenna pattern and ULS location / height data
- Simulate realistic RF system interactions using bandwidth and geometric overlap
  - Matlab using Monte Carlo approach over 1500 iterations
- Results provide a realistic risk-informed view of interference risk to FS that should be the basis of FCC decision making
- Output is depicted as cumulative distribution of probability of aggregate interference at various intensity levels

Results

- I/N Results with low incumbent height
  - Max: -8.5 dB
  - Median: -21.9 dB
- I/N Results with high incumbent height
  - Max: -29.7 dB
  - Median: -36.7 dB
- Simulation shows that LPI Wi-Fi will not cause harmful interference to FS even at a conservative –6 dB I/N threshold

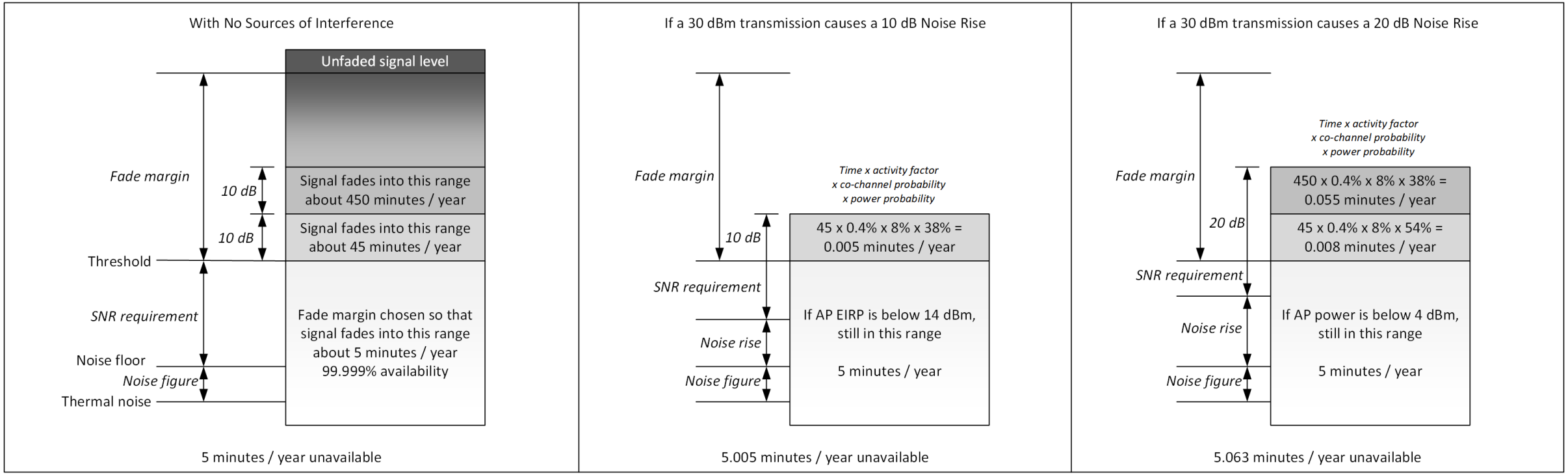


Noise Rise Sensitivity Analysis

Fading and Noise Rise

- Our simulation showed that even with conservative assumptions and dense deployment, no chance of exceeding I/N of -6 dB
- Some corner cases on record suggest specific theoretical and very unlikely situations in which a 30 dBm EIRP Wi-Fi AP would cause a significant noise rise
- But: When a fixed link is engineered with fade margins to provide five-nines availability (99.999%) or higher, even an unrealistically high 10 or 20 dB noise rises creates no increase in FS outage time
  - Given other mechanisms used by FS – frequency and antenna diversity, for instance – availability of critical FS links is engineered to be much higher than 99.999%

Analysis and Results



FS links are designed with fade margin so that outages are 5 minutes per year (99.999% avail)

In a scenario where 30 dBm EIRP Wi-Fi would cause unrealistic 10 dB noise rise, FS availability remains 99.999%

In a scenario where 30 dBm EIRP Wi-Fi would cause unrealistic 20 dB noise rise, FS availability remains at 99.999%

- Even with unrealistically high noise rise, and assuming no other margins, FS links see no reduction in availability
  - Even a reduction in availability would not necessarily lead to an outage because FS utilization will be less than 100%

Results Confirm Oct. 2019 Fading Study

- Showed that even when fading is at its worst for a 95th percentile FS link (worst case), five-nines reliability and more can be achieved.
- Wi-Fi network data confirms this.
  - Wi-Fi network operator results show 7% airtime utilization at 99% percentile which would yield availability to greater than 99.9998%
  - Average Wi-Fi airtime utilization of 0.4% yields FS availability of 99.99999%

95th percentile FS Link with Unrealistic Interference (+20b dB I/N, Duty Cycles < 100%)

Minimal Degradation with Realistic Duty Cycles

- Taking into account real-world RLAN duty cycles reduces the effect even further.
- Link maintains availability greater than five-9s even with 35% duty cycle (far higher than studies predict for 6 GHz RLAN devices).
- As in the earlier example, this does not take into account that:
  - An RLAN is far less likely to be transmitting in the middle of the night/early morning when deep fades are most likely
  - The FS likely has inter-frame spacing between its data packets and may not be operating at maximum capacity
  - The FS has a spatial diversity antenna that is expected to handle 99% of deep fade events
  - Critical links may also have redundant rings, use frequency diversity, and have fiber as a primary or back-up

Interference	Throughput Reduction (Worst Month)	Availability (Worst Month)
Continuous	0.1939%	99.998075%
35%	0.0679%	99.999326%
10%	0.0194%	99.999808%
5%	0.0097%	99.999904%
2%	0.0039%	99.999962%
1%	0.0019%	99.999981%
0.50%	0.0010%	99.999990%

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October 7, 2019 *Ex Parte*, Paul Margie, Harris Wiltshire Grannis

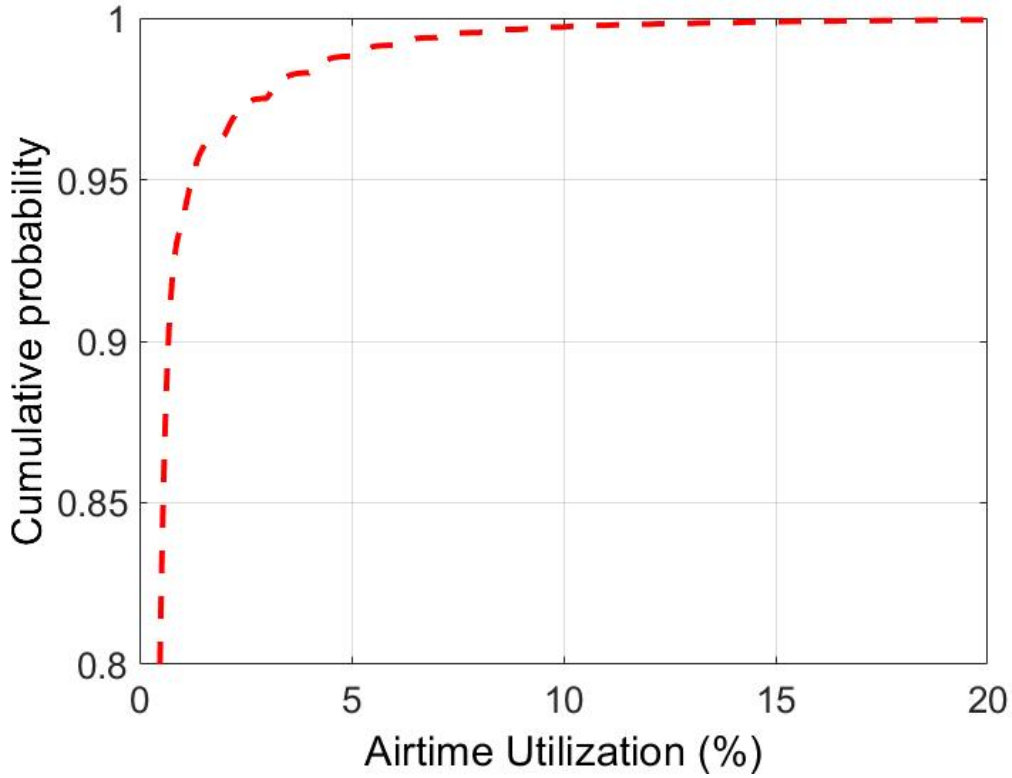
Conclusion

- Analysis of real-world airtime utilization data shows that FS will not experience harmful interference from LPI Wi-Fi operations
- This data validates studies on the record supporting RLAN coexistence with FS; our realistic simulation and sensitivity analysis further validate conclusions
- The FCC should therefore support continued advancement of broadband access technology by making 6 GHz available for LPI unlicensed operations across all 1200 MHz without AFC

Appendix:
Simulation Parameters

Empirical Data on Airtime Utilization

- Airtime utilization contributes to the probability of interference from RLAN to FS
- Collected data from 500k 5 GHz APs across the U.S.
  - Zoomed-in CDF is shown; entire data set integrated into simulation
  - Residential APs were polled; enterprise APs have lighter usage*
  - Airtime utilization includes transmitting and receiving time of an AP
- Weighted average airtime utilization: 0.4%



* See ECC Report 302, "Sharing and compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 5925-6425 MHz", approved May 29, 2019 (p.18); as well as Joseph et al, "Determination of the duty cycle of WLAN for realistic radio frequency electromagnetic field exposure assessment", *Progress in Biophysics and Molecular Biology*, 2012.

RLAN Parameters in the NYC Simulation

- Volume:
  - Use 6 GHz sales forecast (ABI Research) extrapolated to 10-year window (~60% market penetration, which is higher than ECC Report 302)
  - NTIA Internet Use survey provides proxy for Wi-Fi density (75% of households)
  - Adopt a bandwidth-proportionate 6 GHz signal proration (63% of total Wi-Fi bandwidth)
  - Yields an effective NYC 6 GHz Wi-Fi active footprint of ~800,000 access points (approx.1,000 APs/km^2 using 6 GHz)
- Location: Distributed across the NYC market, and layered vertically based on LIDAR building data from USGS
- Bandwidth & Power:
  - Use distributions aligning with ECC Report 302
- Antenna pattern taken from commercial products

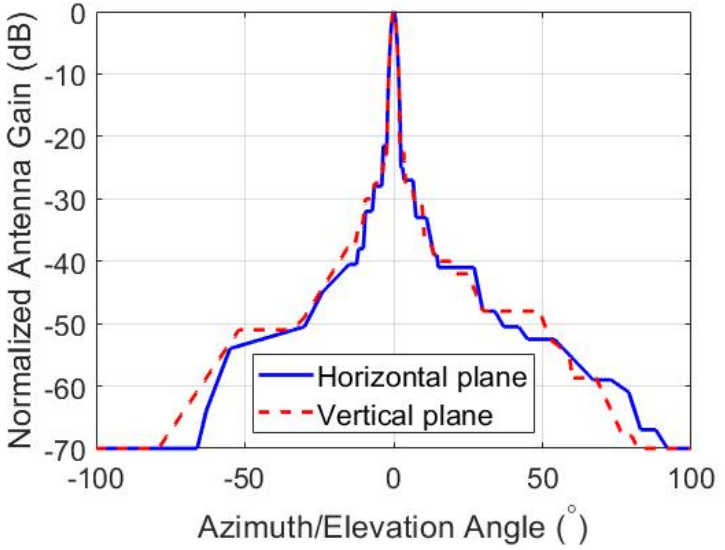
Channel Bandwidth Distribution				
Channel BW	20 MHz	40 MHz	80 MHz	160 MHz
RLAN %	10%	10%	50%	30%

Power Distribution						
Indoor Tx EIRP	1000mW	250mW	100mW	50mW	13mW	1mW
RLAN %	1%	12%	6%	19%	54%	8%

Bandwidth and power values taken from ECC Report 302. Note that power distribution extracts the AP-side information from Table 6 of Report 302, and excludes lower-power client-side information.

FS Parameters in the NYC Simulation

- Representative FS link in Manhattan
  - Two heights modeled – 90th and 10th percentile – based on FCC ULS data for NYC
- 25 MHz bandwidth
- FS antenna
  - Commscope's HSX6-64B dish antenna
  - Max gain: 40 dBi
  - HPBW: 1.7^0 in both vertical and horizontal planes
  - Has more gain in both planes than other antenna on the market, therefore is conservative
- Noise figure: 5 dB (noise floor: -95 dBm)



Bandwidth and Geometric Interactions

- Simulation calculates the probability of channel overlap between RLAN and fixed service, based on the realistic parameters we have outlined
- We also integrate information on RLAN and FS physical deployment
  - RLANs uniformly distributed in NYC market, and allocated height based on LIDAR data
  - FS receiver height taken from in-market FCC data
  - Enables integration of FS antenna pattern information for realistic angle of RF incidence
    - Corner-case interactions are therefore represented in the simulation

Other RF Parameters

- WINNERII Urban path loss model used
  - Appropriate for NYC market that is the focus of this simulation
- Building entry loss represented as a distribution between 10 dB and 30 dB
  - Captures a range of building material factors and indoor AP placement possibilities
  - Consistent with ITU-R P.2109 for relevant cases